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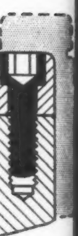

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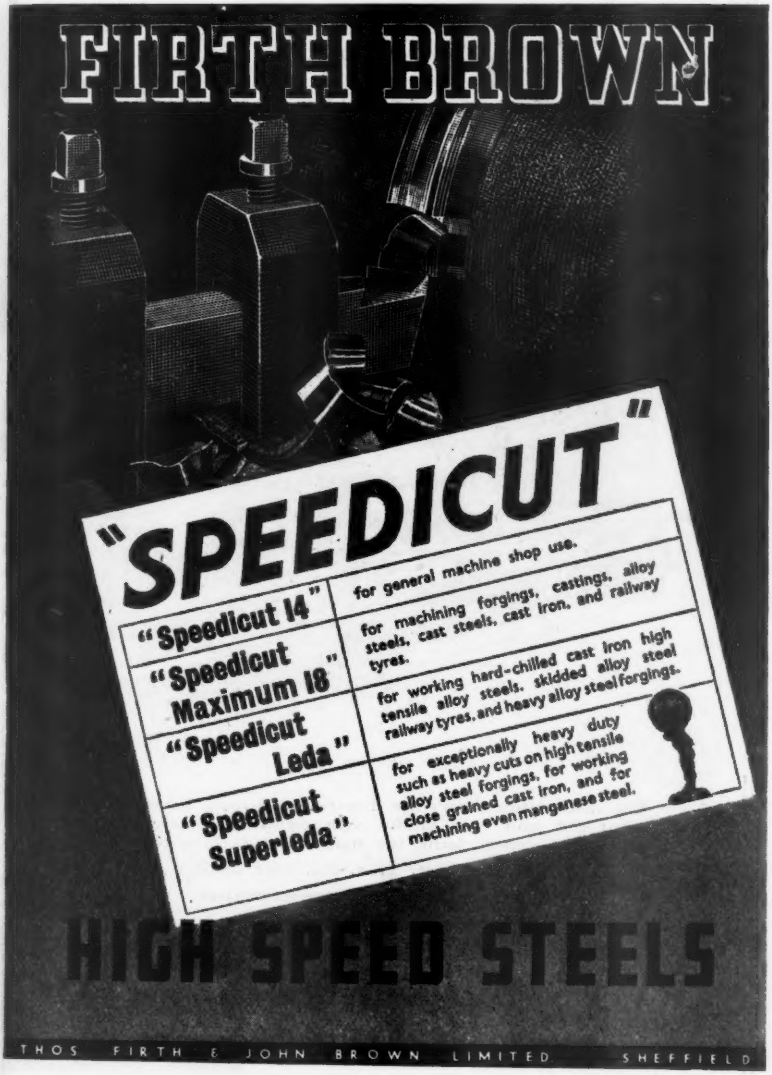
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INSTITUTION NOTES

April, 1947

April Meetings

3rd Nottingham Section. A lecture will be given by H. J. Gibbons, M.I.P.E., on "History of the Large Internal Combustion Engine," at the Victoria Station Hotel, Nottingham, at 7-00 p.m.

9th Luton and District Section. A lecture will be given by W. Neville, Esq., on "Shot Peening," at the Central Library, Luton, at 7-00 p.m.

9th Manchester Section. A visit has been arranged to the Dunlop Rubber Co., Speke, Liverpool.

10th Wolverhampton Section. A lecture will be given by F. J. Everest, M.Sc., A.M.I.Mech.E., A.M.I.E.E., on "Gear Manufacture and Inspection," at the Station Hotel, Dudley, at 7-00 p.m.

12th Halifax Graduate Section. A visit has been arranged to Messrs. A. V. Roe's Works at Chadderton at 2-00 p.m., to be followed by a visit to the Belle Vue Gardens for tea and evening entertainment.

16th Sheffield Section. A lecture will be given by Mr. Tupholme, on "Stainless Steels," at the Royal Victoria Hotel, Sheffield, at 6-30 p.m.

16th Birmingham Section. The Annual General Meeting will be held at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-00 p.m. There will also be a lecture on "Developments in Gear Cutting and Finishing Processes," by F. J. Everest, M.Sc., A.M.I.Mech.E., A.M.I.E.E.

16th London Section. A visit has been arranged to the De Havilland Engine Company. (This visit was originally arranged to take place on 19th February, but was postponed because of the fuel crisis).

17th Glasgow Section. The Annual General Meeting will be held in the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

17th Leicester and District Section. The Annual General Meeting will be held at the Leicester College of Technology, Leicester, at 6-30 p.m., to be followed by sound and colour films.

19th Western Section. A Works Visit to the Aircraft and Engine Works of the Bristol Aeroplane Co., Ltd., Filton, Bristol, has been arranged.

April Meetings—*Cont.*

19th Yorkshire Graduate Section. A visit has been arranged to Messrs. Jowett Cars Ltd., Idle, at 2-30 p.m.

21st Manchester Section. A lecture will be given by E. Percy Edwards, M.I.P.E., on "Broaching—Machines, Tools and Practice," at the College of Technology, Manchester at 7-15 p.m.

21st Halifax Section. A Joint Meeting with the Graduate Section has been arranged to take place at the White Swan Hotel, Halifax, at 7-00 p.m., when J. Ward, Ph.D., B.Sc., M.I.Mech.E., M.I.Mar.E., will lecture on "Engineering Applications of Polarised Light".

21st Derby Sub-Section. A lecture will be given by a representative of the Ministry of Labour and National Service on "Training Within Industry for Supervisors", at the Art School, Green Lane, Derby, at 6-45 p.m.

24th London Section. A lecture will be given by C. E. A. Griffin on "Managerial Problems", at the Institution of Mechanical Engineers, Storey's Gate, St. James' Park, S.W.1, at 6-30 p.m.

25th Lincoln Sub-Section. A lecture will be given by Dr. J. L. Mullins on "X-Rays in Industry" at the Lincoln Technical College, Lincoln, at 6-30 p.m.

May Meetings

1st Nottingham Section. The Eighth Annual General Meeting will be held at the Victoria Station Hotel, Nottingham, at 7-00 p.m.

8th London Section. A lecture will be given by H. W. Hobbs, M.I.P.E., on "A Practical Approach of Research to Industry," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, S.W.1, at 6-30 p.m.

10th Yorkshire Graduate Section. The Annual General Meeting followed by a film afternoon will be held at the Great Northern Hotel, Leeds, at 2-30 p.m. This will be preceded by a luncheon at 1-00 p.m.

10th Preston Section. A visit has been arranged to the Police Motor Training School, Hutton, near Preston.

19th Derby Sub-Section. The Third Annual General Meeting will be held at the Art School, Green Lane, Derby, at 6-45 p.m. to be followed by a lecture by S. Gilbert on "Layout of Factory and Plant for Efficient Production."

31st Yorkshire Graduate Section. A visit has been arranged to Messrs. David Brown Tractors Ltd., Meltham, at 2-30 p.m.

Meeting of Council

The next Meeting of Council will take place on Friday, 25th April, 1947, at the Dudley and Staffordshire Technical College, Dudley, at 11-00 a.m.

Personal

Mr. Mark H. Taylor, M.I.P.E., has been appointed a member of the Engineering Advisory Council, under the Chairmanship of the Minister of Supply, the Rt. Hon. John Wilmot.

Mr. E. Percy Edwards, M.I.P.E., has been appointed Sales Manager of the Lapointe Machine Tool Company Ltd., Edgware, Middlesex. He will continue to operate from the Birmingham office, in addition to the Company's Headquarters at Edgware.

Change of Appointments

An index of senior Members' business addresses and appointments is now maintained at Head Office. It would accordingly be appreciated if all Members and Associate Members who change their business positions would notify Head Office immediately, in order that this index may be kept up to date.

Head Office

Members will appreciate that with a membership which is practically double that of three years ago, coupled with the fact that the Institution is now involved in activities hitherto untouched, the volume of work being handled by the Head Office staff is reaching a proportion which is very nearly beyond their capacity.

In view of this, and until the offices at 36, Portman Square are re-occupied, it is essential that we utilise the existing forces to the best possible advantage, avoiding wherever possible unnecessary work, *e.g.* owing to negligence in failing to cancel their old bank orders, over 400 members have been paying two subscriptions. This has involved: (*a*) extracting details from the accounts; (*b*) writing over 400 letters; (*c*) addressing over 400 envelopes, and (*d*) drawing over 400 cheques in respect of the amounts overpaid.

Members will fully realise the amount of work involved, and are asked kindly to co-operate in any way they possibly can in keeping correspondence down to a minimum.

**South African Association of Production Engineers—
Amalgamation with the Institution of Production Engineers**

Members will be pleased to learn that the South African Association of Production Engineers, at their Annual General Meeting in January, 1947, agreed to adopt this Institution's Memorandum and Articles of Association *in toto*, thereby becoming an integral part of

the Institution of Production Engineers in the Union of South Africa.

Their membership totals approximately 250, made up in grades parallel to those of the Institution of Production Engineers, and the Association has always been regarded in the Union as a very virile and active organisation.

It is a most happy coincidence that this fusion of the two organisations should take place during the visit of the Royal Family, and in joining forces with this Institution, the Association has very definitely added to the status and strength of both bodies. Furthermore, in view of South Africa's industrial progress, no time could be more appropriate than the present for such an amalgamation.

The following messages have been exchanged :

(1) President of the Institution of Production Engineers to South Africa :

"Having received decision of the South African Association of Production Engineers regarding amalgamation with the Home Organisation, am taking the opportunity as President of sending our greetings and good wishes to all your members. Your decision particularly welcome occurring in the year of the Royal Visit to your Country. Norman Rowbotham."

(2) Chairman of Council of the Institution of Production Engineers to South Africa :

"Delighted to learn of success attending negotiations for our amalgamation. Best wishes and a very warm welcome from the Institution. Schofield, Chairman of Council."

(3) The Secretaries of the South African Association of Production Engineers to this Institution :

"Many thanks kind greetings and wishes of President and Chairman. Amalgamation received by membership with every satisfaction. President and Council Members South African Branch delighted with result of negotiations and desire reciprocate greetings and good wishes."

Issue of Journal to New Members

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Important

In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

BOARD OF TRADE
HOSIERY WORKING PARTY REPORT

The Hosiery Working Party Report recently published by the Board of Trade is of the greatest possible interest to all production engineers, in that it emphasises most strongly the urgent necessity for trained production specialists to assist the recovery of the industry which ranks as the third of our textile trades.

The Report—which includes all knitted goods with the exception of warp knitted fabrics as well as socks and stockings—has been compiled as a result of extensive investigation not only in this country, but in the United States of America, and the recommendations made are based on comparisons drawn between the state of the industry in this country and in America, where our strongest competition is to be found.

The Hosiery Industry is an essential and integral part of the clothing industry in the United Kingdom, but its recovery from wartime restriction is being hampered by acute shortages at every stage—shortage of up-to-date machinery, of raw materials, of factory space, and above all, shortage of skilled labour.

While the Report states that the long-term prospects for the industry as a whole are excellent, there is vital need for a well-balanced and carefully planned production scheme if this country is to regain, let alone improve, her pre-war standards in this country.

The Working Party expresses its surprise at the lack of information possessed by the industry on its degree of productive efficiency, and the dearth of specialists in production control. It recommends that wherever possible production engineering techniques should be studied and employed, and urges the importance of corporate technical activity in the industry through the medium of professional institutions such as the Textile Institute and the Institution of Production Engineers.

In taking the long-term view of the industry's requirements, the Report expresses the opinion that the greatest dividends will accrue from the training of technicians, and regard it as significant that nearly all machine builders comment on this shortage.

In this respect it is pointed out by the delegation which investigated the hosiery industry in the U.S.A. that American manufacturers have profited by the care and attention they have given to their production, and in particular to the manner in which they have trained their operatives.

From the short-term point of view, the Report states that it would appear necessary to recruit a small number of young technically trained production engineers, who would have a real opportunity of exercising their talents in the hosiery industry.

The long-term provision of technicians, however, can only be achieved by adequate training methods, and it is suggested that these may be classified under the following main headings :

1. Training inside the firm.
2. Instruction in Technical Colleges.
3. Participation in the activities of Technical Institutions.

It is in connection with (2) and (3) that the Institution of Production Engineers might render the greatest assistance. Close collaboration with the appropriate technical colleges would be essential. Most of the graduates to the industry would possess the Higher National Certificate, possibly in Production Engineering, and the greater demand for the latter course, which seems likely, should be met by the colleges.

The Report continues :

"We also wish to emphasize the important nature of what are often known as professional institutions in completing the training of technicians, and indeed of higher supervisory and managerial ranks also. In the fields under discussion, two institutions come particularly to mind, viz. : the Institution of Production Engineers, and the Textile Institute. The first, as its name implies, is the specialist national body concerned with advancing the techniques of production engineering, and the second is perhaps the most important body covering the technical requirements of the textile industry in general. From our investigations we note that in neither body does the number of hosiery members reach a level proportionate to the size of the industry, although both have local sections in the important hosiery centres.

"We are convinced that first-class Technical Institutions are necessary to promote the science and art of their respective functions, and to encourage those in Industry to raise their knowledge and status by comparison with national standards. With this object in view we recommend :

(a) A closer collaboration between the appropriate technical institutions for the provision of an integrated scheme of training.

(b) A special examination by the Textile Institute of the hosiery industry's position to consider whether its size, status and requirements do not justify even greater specialised attention.

(c) The utmost encouragement being given by top management towards active membership of appropriate technical institutions by their staff, bearing in mind that the individual and corporate activities required by such active membership are likely to provide also sound supervisory and managerial training."

(NOTE—Copies of the Hosiery Working Party Report may be obtained from H.M. Stationery Office, price 3s. 6d.)

IRON CASTING SUPPLIES

The widespread interest aroused by Sir Alfred Herbert's article on "The Art and Mystery of the Foundryman," which appeared in the January issue of the *Journal*, is evidenced by the fact that we have received from the Ministry of Supply the following comments, which members will no doubt find of great interest:

"Sir Alfred Herbert's memorandum has been studied with much interest. You can be assured that the facts of the situation described by Sir Alfred have long been known to us and to the Ministry of Labour and that all practicable steps are being taken with the cognisance and co-operation of the Trade Unions and Employers' Organisations to overcome the shortage of labour in the ironfounding industry.

The efforts to rebuild the strength of the industry began immediately after the end of the war and have already achieved a fair measure of success, as is evident from the fact that between October, 1945, and October, 1946, the labour strength of the iron foundries rose from 100,100 to 128,300. Thus there was a net increase of 28,200 in the twelve months, and over the same period the rate of production of iron castings increased from around two million to just over two and a half million tons a year.

"Among the steps taken that have contributed to the expansion achieved since the war in the strength of the iron foundries the most important are probably:

(a) The release of over 4,000 former foundry workers under Class "B" from the Forces in addition to the thousands more released on an age and length of service basis.

(b) The industrial agreements signed in the Spring of this year between the Employers and Trade Unions whereby the Trade Unions made important concessions to facilitate the training of unskilled men on demobilisation for certain skilled occupations, the upgrading of machine moulders and the acceptance of men up to twenty years of age as apprentices.

(c) The authorization of schemes involving varying degrees of mechanization, the total cost of which to date already exceeds three million pounds, and so far as can be foreseen, is expected to continue at the rate of around two million a year.

(d) The circulation of an informatory leaflet prepared by the Ministry of Labour in consultation with the Trade Unions and Employers' Organizations both to Education Officers in the Forces and to Employment Exchanges and Juvenile Employment Bureaux to enable them to advise on the possible openings in the iron foundries.

"The industry is alive to the fact that there is a great deal that it can do to improve working conditions and amenities. A special Ministry of Labour Committee on which both sides of the industry are represented, has been examining the problem and is expected to report shortly. Improvements in this field are also, of course, facilitated by the mechanization and modernization of production methods to which reference has been made. The Iron and Steel Board are paying particular attention to this aspect of the problem.

"The current vacancies in the ironfounding industry total approximately 7,000, of which about half are for skilled men. As part of the effort to overcome this short-term problem you will know that a scheme is afoot for the recruitment of up to 2,800 Italian foundry workers, the first of whom are expected to arrive in this country early in January. The demands notified to date for Italians and agreed with the workers total just over 800, and we are hoping that increased demands will be stimulated once the Italians start to arrive, provided, of course, they come up to expectations. The industry is also being consulted about the introduction of Polish workers. Finally, publicity for British workers is being arranged by the Ministry of Labour in consultation with this Ministry, apart from the publicity activities of the Council of Ironfoundry Associations and other trade organizations. The efforts of the Institution of Production Engineers to encourage young men to go into the higher positions in the industry is a valuable contribution in a special field.

"You will appreciate from this brief review that this problem is being tackled by a variety of methods in an effort to maintain the rate of increase in labour strength that has been achieved in the period since the end of the war."

"HYDRAULICS AS APPLIED TO MACHINE TOOLS"

By W. WHITWORTH TAYLOR

Presented to the Institution of Production Engineers, Derby Sub-Section 20th January, 1947.

The application of hydraulic power to machine tools is now barely twenty years old. During this time not only has man's conception of hydraulics undergone a revolution, but hydraulic power transmission has become almost paramount in certain types of machine tool drives.

Just why has this come about ?

Undoubtedly the first applications of hydraulics to machine tools were chosen because they gave so many desirable features in relatively compact and simple constructions. These were compelling reasons and would alone explain the present wide adoption of hydraulics to table feeding mechanisms.

During the initial ten years of development, however, a conception of hydraulics arose which differed fundamentally from the older idea of hydraulic head associated with hydraulic lifts, presses, and so forth. This was the "hydraulic electric analogy" which made possible the analysis of hydraulic circuits in much the same way as electric circuits are analysed. The three elements of this conception are :—

(1) Pumps displace fluid quantities Q (cu. ins./min.).

(2) Fluid displacements are resisted by hydraulic resistances R (units of resistance).

(3) Resisted displacements give rise to pressures P (lbs./sq. ins.).

The relation between these three elements is expressed in practice by the equation :—

$$P = QR.$$

The analogy between this equation and Ohm's Law is striking. Just as Ohm provided a foundation on which the science of electricity has been erected, so has the hydraulic equation provided a basis on which hydraulics have reached new heights as exemplified in the balancing valve, the sequential valve, the constant delivery throttle valve, the tarry valve, the servo valve and so forth.

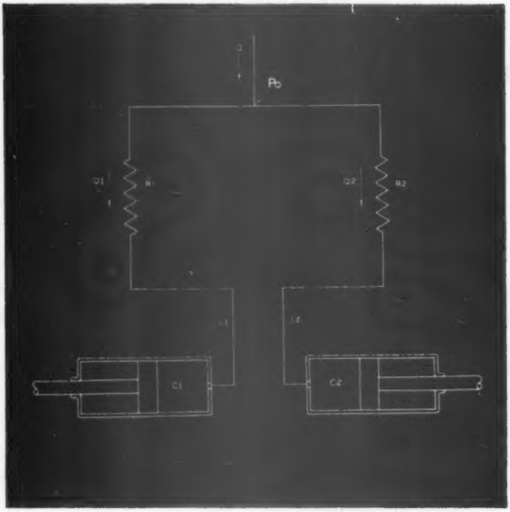

FIG. 1

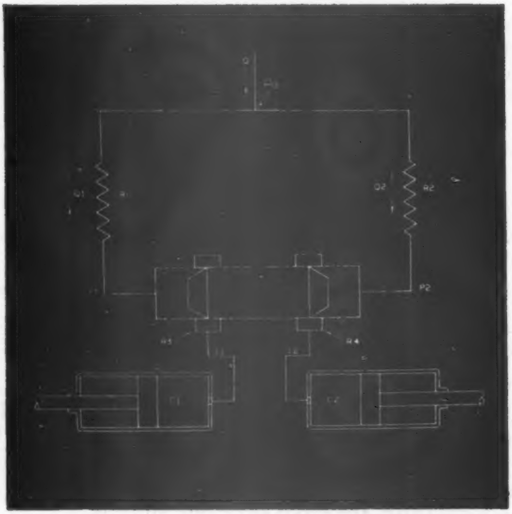

FIG. 2

The Balancing Valve.

Assume we wish to divide flow Q in Fig. 1 into two lines L_1 and L_2 through two resistances R_1 and R_2, provided that the two cylinders C_1 and C_2 offer no resistance, by the hydraulic electrical analogy, the ratio of flow in the two lines will be inversely proportional to the two resistances thus :—

$$\frac{Q_1}{Q_2} = \frac{R_2}{R_1}$$

In practice the two cylinders will have resistances depending on their respective loads and the flow relationship shown above will not hold.

The balancing valve is an ingenious mechanism which overcomes the difficulty.

Let us assume (Fig. 2) that owing to an increase in the load on cylinder C_1, it tries to slow down. This would normally result in an increase in pressure P_1, but, since the construction of the valve is such that P_1 always equals P_2, what happens is that the valve itself moves to the right, thereby increasing resistance R_4 and decreasing resistance R_3, thus re-establishing P_1 equal to P_2 and hence the flow relationship $Q_1/Q_2 = R_2/R_1$, no matter what the load on either cylinder.

The Sequential Valve.

It is sometimes necessary to secure a sequence of slide motions such that when one slide motion has finished, the next in sequence is started. If the first slide is to have no motion at the instant the next slide is to start moving, it will not be possible to use a trip dog mechanism. The sequential valve gives the required action. In Fig. 3 is a series of three pistons with two valves. The action in this case is sequential. Oil is delivered from the pump, enters line B, and since it cannot enter the valve, it passes through the resistance and actuates the movement of piston G to the left. When the piston reaches the end of the stroke (Fig. 4) flow stops in line A, and since the pressure on both ends of the valve is the same and the area on the left end of the valve is greater than that on the right, the valve will move to the right, and oil will pass into line C. From that point on the action consists of the movement of piston H, in the same manner as G. When H has moved to the extreme left the second valve Y will move to the right and piston J will go into motion. The complete sequence of motion is achieved when all three pistons have moved to the left.

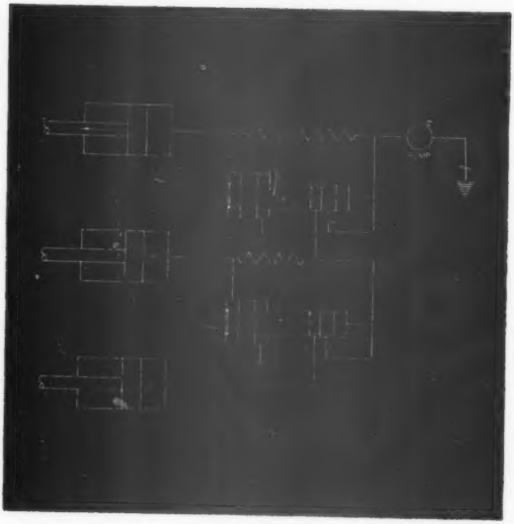

FIG.3

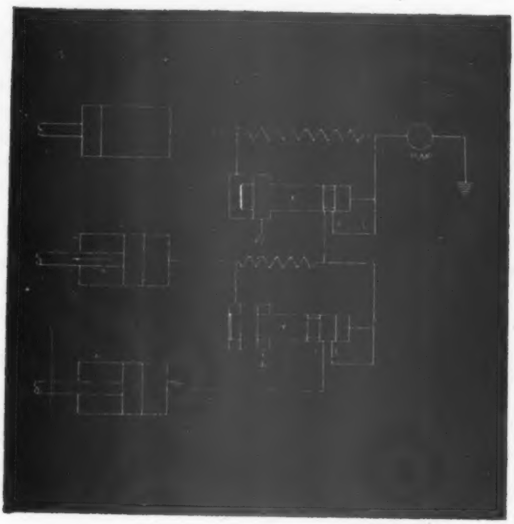

FIG. 4

Constant Delivery Throttle Valve.

The simple resistance or throttle valve is a poor means of controlling volume since, by the hydraulic equation, this latter will vary with change in load W or pressure. By the addition of a reducing valve in the line just ahead of the throttle (Fig. 5) almost complete compensation is obtained against variation in load. The pressure P_T ahead of the throttle is determined by the pressure of the reducing valve spring and hence remains substantially constant irrespective of load W. Since the pressure drop across the throttle is held constant, this always passes the quantity of oil determined by its own resistance setting.

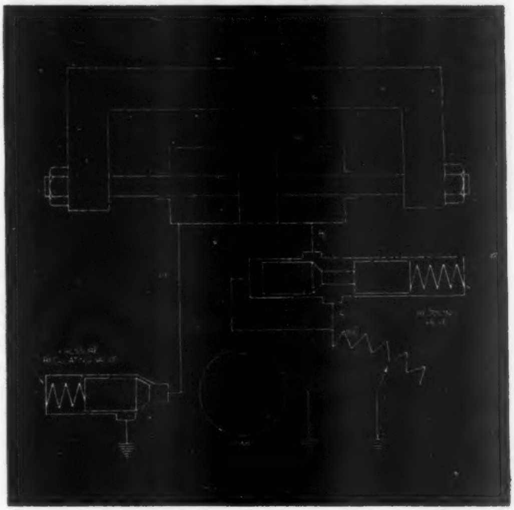

Fig. 5

The Tarry Valve.

In Fig. 6 the valve is in the position shown, and the reversing valve has been reversed. Therefore the path of the oil will now be in the direction shown by the arrows. Since the oil will not be able to pass the left-hand check valve, it will pass through the left-hand resistance and very slowly move the tarry valve to the right. In the meantime the motor is blocked from receiving oil. Finally, the valve will have reached its extreme right-hand position and flow through the valve will be re-established (Fig. 7) until the next reversal. The valve

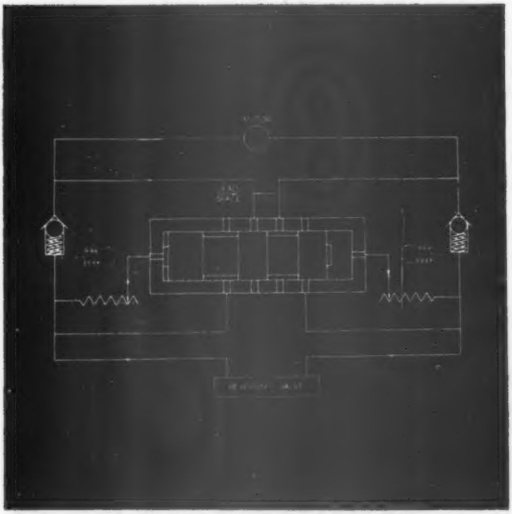

FIG. 6

therefore must shuttle at every reversal. The time required to shuttle is the tarry time and will be dependent on the setting of the resistances. With the valve in the extreme right-hand position the moving member will reach the end of its stroke and reverse the reversing valve. The action just explained will now reverse itself. In the case shown the amount of tarry will be the same at both ends. In order to have tarry unlike at both ends, check valves are introduced into the system, as shown by the dotted lines, and the amount of tarry is controlled by the variable resistances at each end.

The Servo Valve.

Probably the most important application of the servo valve to machine tools is its use in contour tracing. In Fig. 8 is shown the simplest type of tracer which is designated the 180° tracer. In this tracer, the axis of the tracer finger is in the plane of the contour. The slide movement which is parallel to the axis of the tracer finger is controlled directly by the tracer valve, while the slide movement at right angles thereto is reduced in accordance with the tracer deflection. There are three basic positions of the tracer finger which have been named arbitrarily: over-deflected, neutral and undeflected.

When the tracer, shown in Fig. 8, is undeflected, the valve is so ported that the slide moves downward. When the tracer is in the

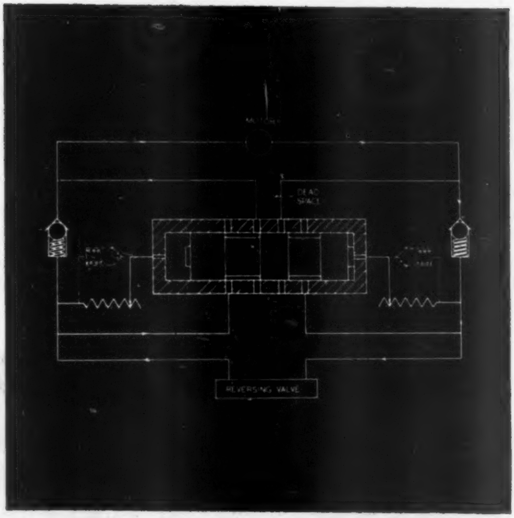

FIG. 7

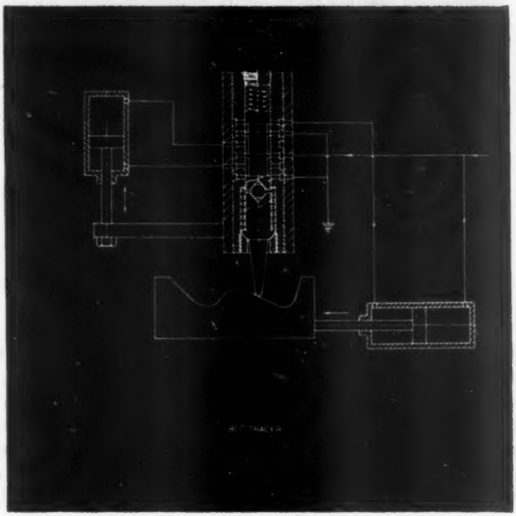

FIG. 8

neutral position, no vertical movement takes place while the over-deflected position causes the slide to move upward. Thus the tracer is always seeking contact with the master. When a sharp slope is encountered, the horizontal component of movement is decreased by the throttling ports at the top of the valve. When a vertical slope is encountered, the horizontal component is stopped by the closing of these throttling ports. It is apparent that contours which exceed 180° of included angle cannot be traced.

In the 360° tracing method, the axis of the tracer finger is placed perpendicular to the plane of the contour. In Fig. 9, this scheme is shown schematically. The servo tracer valve is used only as a directional servo. The tracer valve corrects the directions of motion only, the feed components being determined by other means controlled by the tracer mechanism.

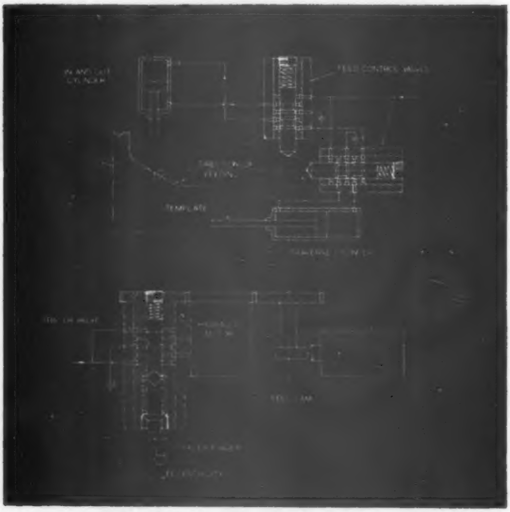

FIG. 9.

To obtain this result, the tracer finger is made eccentric to the main tracer axis. Geared to the tracer body, as shown in Fig. 9, is another eccentric which controls the setting of the feed control valves or directional valves. In operation, if the direction of the tracer eccentric is such that it interferes with the master, the tracer over-deflects, which causes the servo motor to rotate the tracer counter-clockwise. This reduces the tracer deflection and at the same time

corrects the angle at which the directional eccentric is pointed. Thus the feed components are corrected to give the correct direction.

In this way, the motion of the tracer assembly with respect to the master is always seeking a direction which is tangent to the curve of the master.

The traverse cylinder controls the table on which the master and work is mounted, while the in and out cylinder controls the ram upon which the tracer and cutter are mounted.

The rate of feeding is controlled by the magnitude of the eccentricity of the feed cam or eccentric.

In Fig. 10 is shown a servo valve adapted for hand or power operation of a machine tool slide. The piston rod and lead screw are attached to the slide which it is desired to move. The cylinder and servo-valve bushing are attached to the main frame or base of

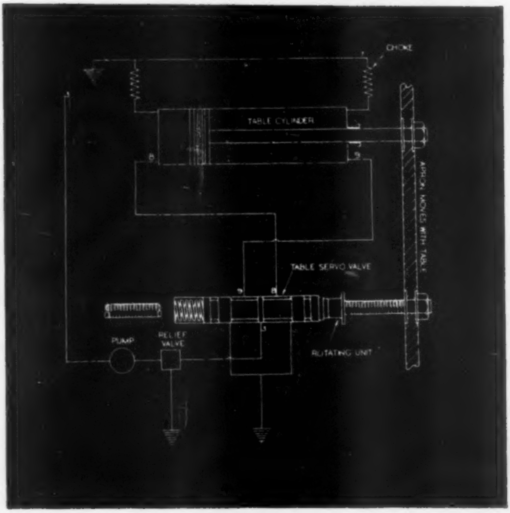

FIG. 10

the machine. The servo valve spool also acts as a nut on the lead screw and may be rotated either by hand or power. Supposing the nut is rotated so as to move the servo spool to the left, hydraulic flow is immediately set up in the cylinder to push the slide to the right. This motion will continue until the servo spool has been centralised. Since the servo valve is sensitive to displacements as small as 0·0001 in., the mechanism is very accurate. Backlash

between nut and lead screw is eliminated by light endwise constraint of the nut by spring or other means.

Fig. 11 illustrates a vertical machine equipped with hydraulic servo valve feed to all three slides. Handwheels A, B and C rotate the servo-nuts of the table, ram and vertical motions respectively,

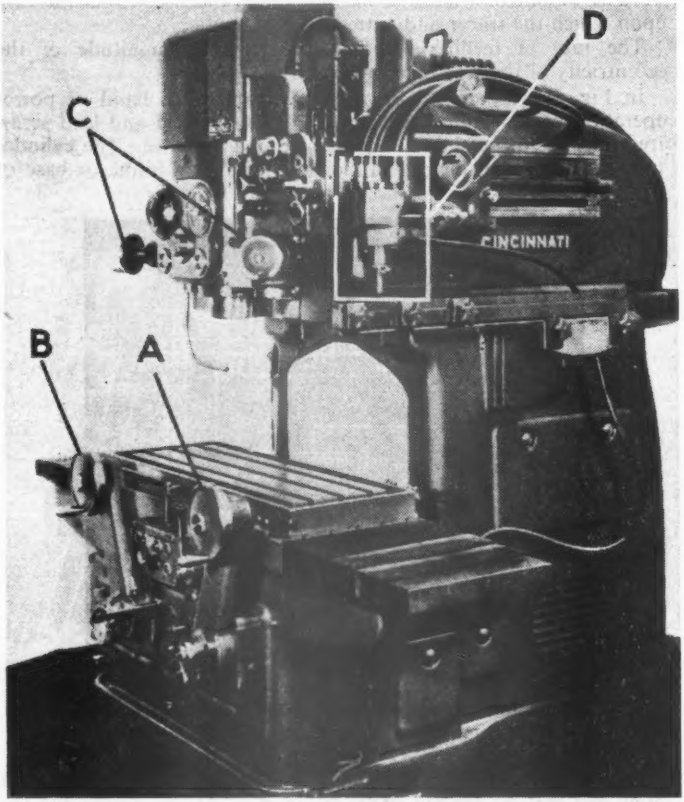

FIG. 11

for finger light, accurate but at the same time rigid positioning of these three slides. Simple variable feed drives to these same nuts controlled by directional levers engage any desired feed rate or rapid traverse in either direction. The hydraulic depth control

tracer D (180° tracer) converts the machine at will into a die sinker. The action of deflecting the tracer from its hanging position automatically disconnects the vertical servo half nut from the vertical lead screw and puts the tracer valve into action.

Fig. 12 shows a four-spindle automatic profiler equipped with a hydraulic 360° tracing box A. This box operates on the principle illustrated in Fig. 7. The operation of the machine consists of

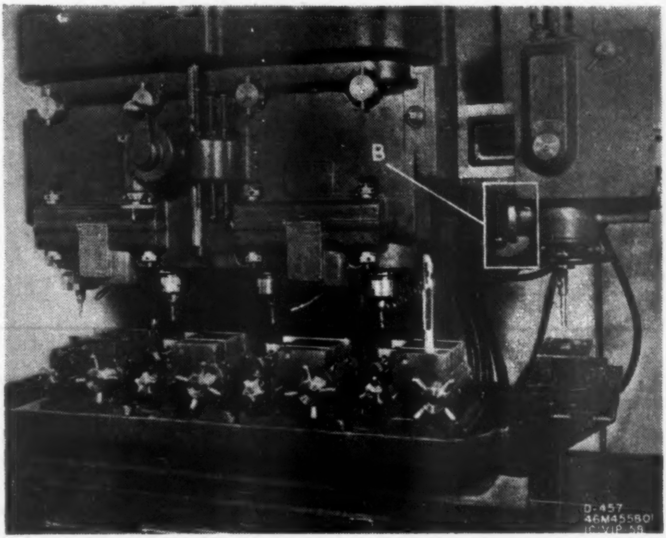

FIG. 12

loading the four work stations, lowering the four spindle head tracer box assembly so that the tracer enters the template and raising the feed quadrant B to the desired feed rate. The machine immediately starts to feed in the direction of the arrow on the tracer steering wheel. As soon as the tracer contacts the template, the tracer assembly swings till the arrow is tangent to the form and it continues feeding right round the form with the four spindles cutting.

Fig. 13 shows a section of a so-called filmatic bearing which utilises the hydraulic pumping action of the rotating journal, arising out of the viscous drag on the oil surrounding it, applied to five wedge-shaped resistance gaps formed between the journal itself and

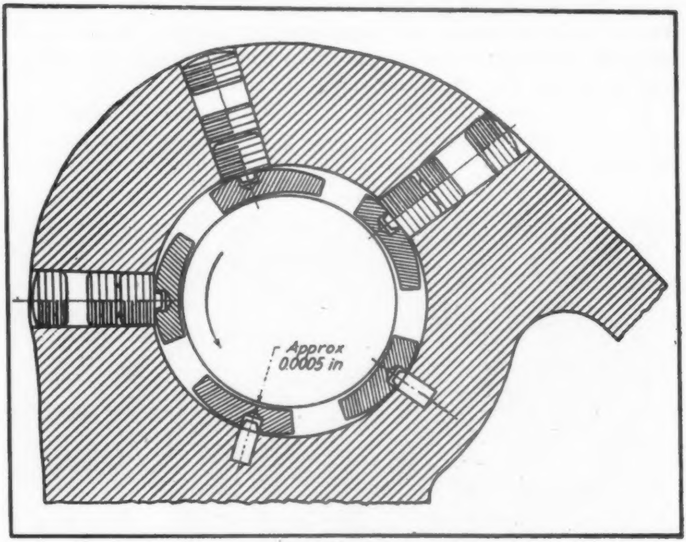

FIG. 13

the five self-compensating shoes to produce five regions of high radial pressure on the journal which literally lock it in a fluid vice.

Fig. 14 shows a special duplex milling machine arranged, with four vertical spindles mounted on rams and carrying four sets of cutters for milling locating pads on two sets of automobile crankshafts at one time. Schematically the complete path of one of the cutters is illustrated in Fig. 15. Fig. 16 shows the hydraulic circuit for this machine. The circuit can be identified as a complicated modification of the locked circuit, in that the feed rate is determined by the displacement of the variable delivery (VD) pump whose intake connects to the back pressure line and which discharges into the forward pressure line. Pressure leakage is made up by the booster pump which discharges into the forward pressure line. The differential relief valve relieves the forward pressure when the sum of the forward and back pressures exceed the spring setting. At A resistance R betrays a sequential valve, in this case called an unloading valve. Its function is to maintain forward pressure in the main cylinder so that it does not move during the " in-feed " cycle. As the return oil from the two cylinders B and C ceases to flow through resistance R, the valve moves to the left, restoring the normal circuit to cylinder D. The balancing valve at E will also be obvious.

Its function is to maintain equal rates of infeed on cylinders B and C.

At F is a delay trip valve which functions as follows. When the table reaches the end of its short feed cycle, a dwell is required to enable the cutters to clean up. The table runs into a positive stop ; as it does so, the back pressure in cylinder D begins to fall, slowly escaping through resistance R_3 to the tank. This allows the main spool of the delay trip valve to move slowly downwards, urged by the spring at the top. When it completes its downward travel oil is shunted to the bottom of the right-hand spool, which connects ratchet G to pressure and sets the cycle in motion again.

This circuit is cited to show not only the similarity which exists between electric and hydraulic circuits, but also the sort of complexity which can arise when complex results are desired.

Fig. 17 shows a hydraulic machine sinking a crankshaft die.

Coming to rather heavier work, Fig. 18 shows a hydraulic horizontal milling machine milling the side of a locomotive connecting rod. By the use of hydraulic servo motions to the table, the cross ram and the vertical slides, it is possible to hand manipulate this machine with the little finger, even when positioning the table and carrier to do work of this kind.

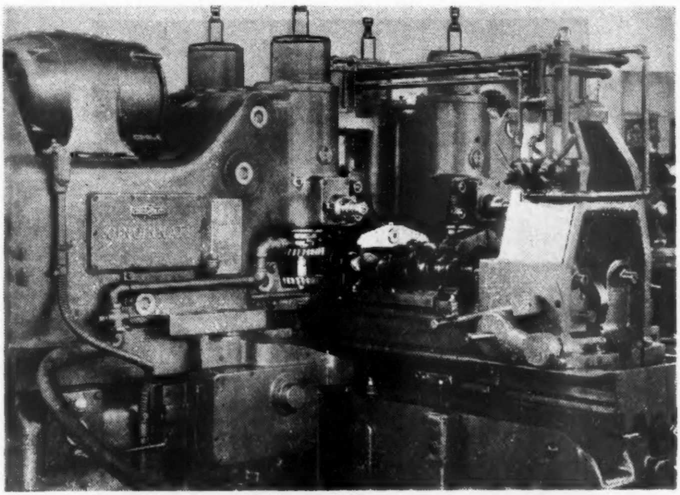

FIG. 14

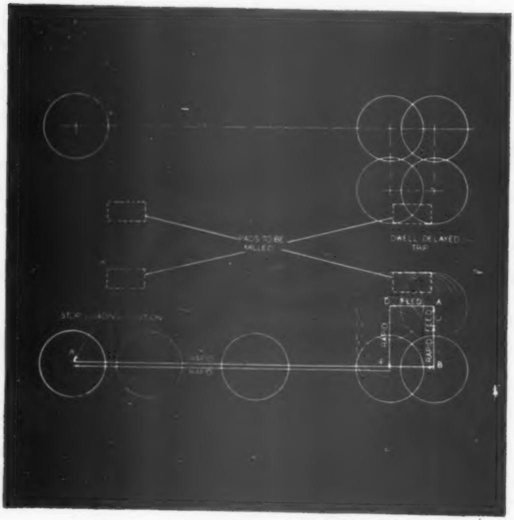
PADS TO BE
MILLED
DWELL DELAYED
TRIP
FEED
A
RAPID
FEED
RAPID
B

FIG. 15

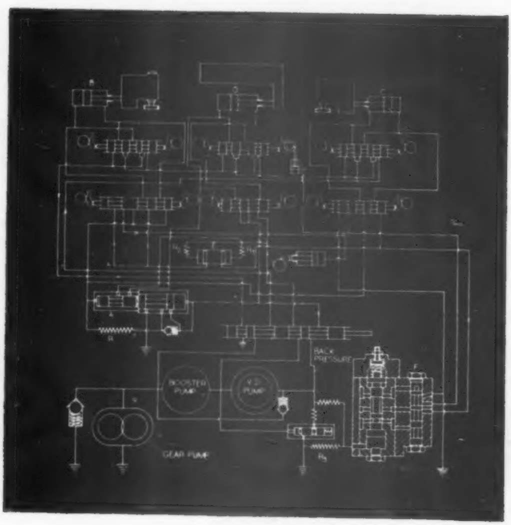
BACK
PRESSURE
BOOSTER
PUMP
V.D.
PUMP
GEAR PUMP

FIG. 16

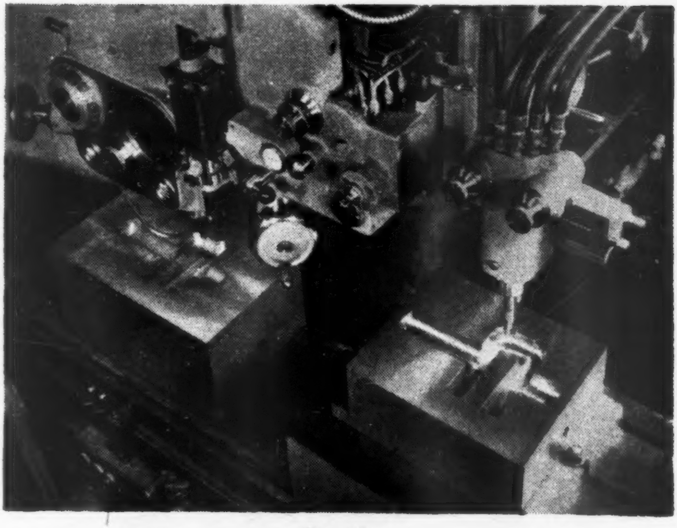

FIG. 17

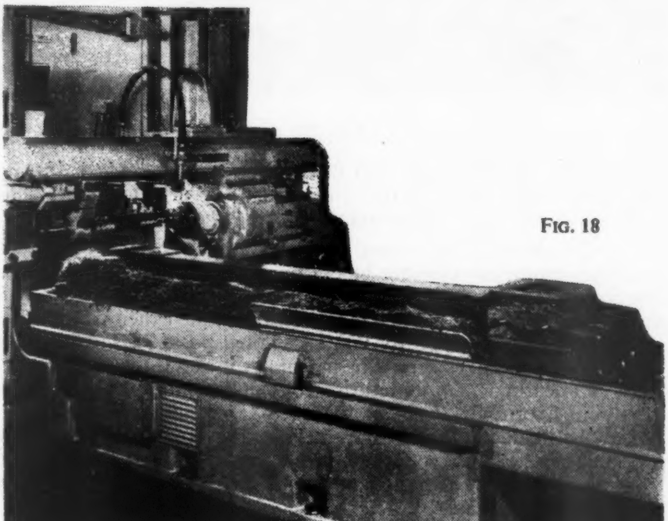

FIG. 18

Fig. 19 shows a big end of a locomotive being automatically profiled on a hydraulic miller equipped with 360° hydraulic tracer. The tracer can be seen following the template, while the cutter reproduces the form on the end of the component. Even though the

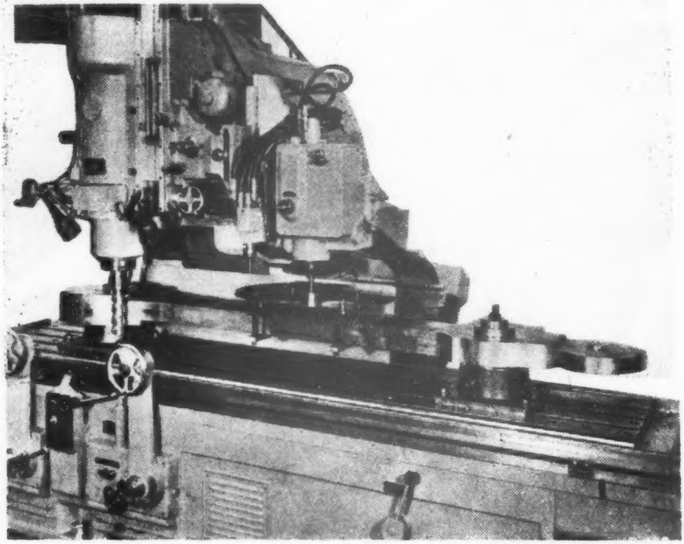

FIG. 19

contact between the tracer and the template is a matter of ounces, the positioning forces on the cut are of a very high order, while accuracy is measured in thousandths of an inch.

Fig. 20 shows a horizontal surface broaching machine which machines motor car cylinder block tops and bottoms at the rate of one complete block per minute. The blocks come down the conveyor at the right, enter the right-hand fixture A, which then clamps and swings up hydraulically to the broaching position shown. The horizontal ram makes a pass to machine the sump face and crankshaft cap bearings. On its return stroke, it machines the top, which is now in fixture C. Rollover fixture B serves to reverse the component between the two fixtures. Hydraulics are a natural choice for equipment of this type where heavy loads, complex motions and fool-proof reliable operation must be achieved without unduly complex mechanisms.

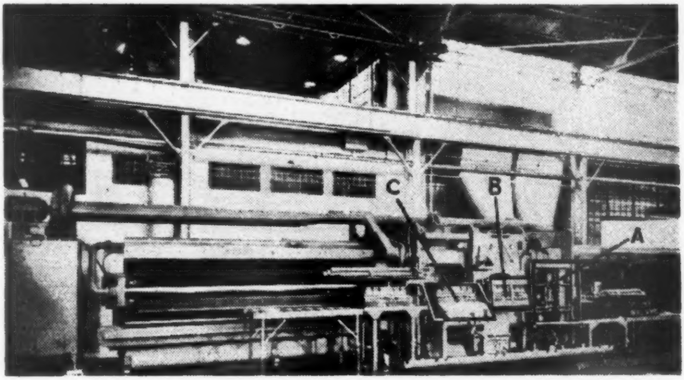

FIG. 20

So you can see that hydraulics are now applied to machine tools not only to move heavy loads, but to effect time delays, sequential operation and a multitude of other tasks, some of which at one time seemed to be the proper function of electrical equipment. To what extent hydraulics will retain their lead cannot be forecast, but when looking for complex reliable results allied to simple compact construction, the machine tool designer of the future will always have an attractive selection in what hydraulics have got to offer.

Acknowledgment.

The author desires to make particular acknowledgment to Albert H. Dall, Assistant Director of Research, Cincinnati Milling and Grinding Machines, Inc., from whose writings as well as from those of other members of that organisation the author has drawn freely.

"PLAIN SLEEVE BEARINGS—MATERALS AND DESIGN"

By W. H. TAIT, M.I.Mech.E., F.I.M.

DISCUSSION

(NOTE—Mr. Tait's paper was published in the March issue of the Journal.)

The CHAIRMAN said there would be general agreement that the lecture that evening had been typical of the kind that the members liked to have. He had been gratified to hear the author say that he was prepared to be awkward by refusing to give tables. Production engineers were frequently accused of being awkward because they would not make specific statements which covered all cases, and for an academic person such as the author to refuse to give tables and to talk in such a delightful way was just what they wanted.

Most of the audience would have obtained from the lecture a different conception of bearings in many ways from that which they had had before, and they would do well to pay heed to the author's injunction to consult when in difficulties those people who lived their lives with the problem and specialized in it.

He would like to ask what method of lubrication of tight white metal bearings was recommended if the ordinary normal application was likely to cause a seizure.

MR. TAIT said that where the spindle not only rotated in the tight bearing but travelled through it, the lubricant was put on at very long intervals with a very slightly oily rag, wiped on as it travelled through, but it was also maintained there by having a slot in the sleeve bearing with a felt pad in the slot which retained a small amount of oil. A very thin lubricating oil was used in this way. Each specific application called for careful thought, and it would be necessary to consider in any particular case how to put the lubricant there. In general, however, it would be spread by a close-textured piece of felt pad, fed with a thin oil at a very slow rate.

MR. BURT referred to the question of the relationship between the diameter and the length of the bearing. The shaft diameter, he said, was usually fixed in accordance with the load transmitted by the shaft. Would there be any advantage in making a sleeve bearing extra long to give it a long life, particularly in a case where the lubrication might be poor ? He was thinking of the use of the oilite bearing to which the author referred. He saw some bearings

recently in which there were two circular grooves placed at the extreme ends of the bearing. The oil grooves went to within 1/16 inch of the end of the sleeve. He had been told that that groove prevented the oil from working out, and he would like to have the author's opinion.

MR. TAIT said that generally speaking very little was gained, particularly with the oilite type of bush, by making them long. He had not had the experience of the oilite type that he had had of sleeve bearings, because his company did not make them, but he was told that even with the oilite type of bush the figure of about 0·7 was correct. Dr. Clayton, who had had something to do with laying down the standards for oilite bushes, was present, and would no doubt give his ideas about the relationship of length and diameter.

With regard to the other question, the Germans had found that in the oil-retaining type of bush the addition of the grooves referred to did in fact prevent the oil escaping from the ends. They did not go into much theory about the reason for that ; they just reported experiments to that effect, and he was prepared to believe them.

DR. W. CLAYTON said it had been a real pleasure to listen to the lecture. There were dozens of points in it which he thoroughly agreed with, and was glad to see publicised. He thought that the conclusions were very sound. Thus the rule about using the softest material that would do the job from the strength point of view was excellent. He also liked the author's idea of cutting down the number of materials ; the author named two of one sort and one of another. Personally, he felt that there was a great deal of misunderstanding about the number of materials needed for even a variety of applications ; if the design is right, then relatively few materials are necessary. He agreed thoroughly with the author on the question of standard sizes, not merely from the point of view of economic manufacture, but also because he thought that standard bushes could be made more accurately by a manufacturer specially equipped for the purpose. He greatly appreciated hearing those *ex cathedra* statements from such an expert as the author.

He had been a little disappointed, however, at the author's pessimism about obtaining fluid films in bearings. As a lubrication advisor, he himself often said that it was his job to make sure that fluid films were obtained and not boundary lubrication. When the author began, he felt that he was making a mistake in saying that the fluid film played such a small part, but by the time he reached the end the author had made out a very strong case for the important consideration of the departures from the ideal, leading to boundary lubrication conditions.

However, he felt that some of the low friction which was obtained with what the author called "film" lubrication (boundary) was,

in fact, due to a large proportion of fluid film lubrication at the same time as a certain amount of boundary lubrication. Thus, where the contacts occurred on a number of high spots of the surfaces, there was a tendency to set up local fluid films and that reduced the friction. Again, in connection with the author's reference to the high loads that could be taken with bronze, he recalled a case in America some time ago where a bronze block was pressed against the edge of a steel disc in an experiment to see whether naphthenic oils differed from paraffinic oils in their boundary lubricating properties ; but after readings had been obtained, it was suggested that fluid film might after all be present, and it was eventually shown that the apparent differences in boundary friction were in entire accord with calculated friction, allowing for the effect of the high local pressure (of some 20,000 lb. per sq. in.) on viscosity. It should be noted that a block rubbing on the edge of the disc gives conditions entirely contrary to those which one would choose for fluid film lubrication.

In the case of the gudgeon pin, he would say that it was a largely fluid film, not boundary film. In support of that, he would quote results obtained by his quondam colleague Mr. Fogg in some experiments at N.P.L. on an oscillating bearing some time ago ; even when criss-cross grooves were cut in the bush, leaving only diamond-shaped facets, it was difficult to get boundary lubrication, fluid effects being evident even at as low as three oscillations a minute. In the case of the gudgeon pin, it was of interest to consider the difference between a four-stroke and a two-stroke engine. The two-stroke, with the load constantly in one direction, did squeeze out the film, and it seemed necessary to provide grooves to allow the oil film to be renewed. With the four-stroke there was a reversal of the load, and the film got in and there was not time to squeeze it out again during the oscillation of the gudgeon pin.

There was one small point of nomenclature to which he would like to refer. The author mentioned "pad" lubrication. What was meant by that was no doubt generally understood, but the author also referred to film lubrication ; personally he had always regarded film lubrication as meaning fluid film lubrication, whereas the author seemed to mean boundary lubrication. He would suggest supplementing the lecture by making these terms clear. It avoided much confusion to talk about "width" and not "length" ; "length" had come to mean the length in the direction of motion. Moreover, he would say that rarely did one get "metal-to-metal" contact ; it was nearly always boundary film to boundary film. Sometimes when the author referred to film lubrication, he thought he was probably obtaining mixed boundary and fluid lubrication.

Reference was made in the lecture to the thinness of bearing metal. He attached importance to that from the point of view of

putting up the fatigue strength of the white metals very considerably ; he had on numerous occasions emphasized it as one means of pushing these most useful white metals into the range that was covered by the more troublesome copper-lead lead-bronze.

He had been very interested in the reference to grinding wheel spindles. He thought that in the case of the very close-fitting bearing it was air-lubricated. The oil was put on as a thin film and it prevented metal-to-metal contact. Then at speed, air pressure films formed in between the parts lubricated with oil . The small clearance was appropriate, because if one wrote Z/P in the fuller form, $Z/P \times D^2/C^2$, to bring the clearance into the formula, then the small clearance compensated for the very small viscosity of air.

He was very fully in agreement with the lecturer on the need for care in force fitting and in screwing up bearing caps. A bearing could be very carefully made (say), diamond-turned with a specially precise lathe, and then in mounting squeezed entirely out of shape, and often taking up the whole of the clearance which had been carefully allowed for. He had had an experience some time ago with a bronze bush forced into a steel sleeve, in which, due to the very high temperature of the bearing, the bronze bush always worked loose. The cure was to make the interference fit very much less.

He supported the author in his recommendation of the use of cast iron as a journal material.

He would like to have an illustration of the oil window which had been referred to, as a new means of feeding oil to the bearing.

On the question of width of bearing, he agreed thoroughly with the author, but was a little surprised that, as a bearing manufacturer, he did not get called upon to depart widely from the 0·7 which he quoted as the optimum width/diameter ratio. There was a strong demand from engineers in general for wider bearings, but he himself felt that, particularly in view of all the factors which the author had emphasized regarding departures from the ideal, a long bearing was very much to be deprecated. The increased load-carrying capacity which theoretically should be obtained was not in fact forthcoming. In connection with the point already raised about porous bearings, he had pressed very strongly in the discussion at the B.S.I. for them to be kept short, but he had not succeeded very well, and there were many long ones quoted. The people who used them would persuade him that they were necessary, but he was still a little recalcitrant ; it was even recommended that long bearings should be made up with several standard ones in line.

As regards the enquiry about end grooves, he thought they were intended to serve a purpose which was already occurring naturally in many bearings, particularly where there was limited oil supply ; the oil was squeezed out to the sides of the bearing (forming a bead

of oil) on the pressure side and sucked in again in the negative pressure region. There could be a regular circulation sideways, and he thought the object of putting a groove at each end was to prevent the oil escaping by spreading along the shaft.

MR. TAIT remarked that he would have to be careful, because with Dr. Clayton it was easy to start an argument which might go on all night! It was obvious that one of their differences was due to his not having used the conventional wording. He had used the term "oil pad lubrication" after recent discussions in America, where "oil pad" or "oil pancake" were quite usual terms. He would in future, however, take care to use more conventional terms. What he had in mind when he talked about fluid lubrication and boundary lubrication and metal to metal contact was just this. Full fluid lubrication postulated as a basis that all the friction takes place within the oil and that the bearing materials and the shaft materials did not enter into it. If that were absolutely the case, as he believed it was the case with some of the beautiful testing machines which he saw in America, marvellously rigid, beautifully made and often designed to show that the particular bearing material which the man was advocating was the best of the lot, he believed that the bearing material would not be in contact at all and all the friction would, in fact, take place within the oil. It was well known, however, that in practice that did not happen, or one bearing material would not differ in its practical behaviour from another.

When he spoke of there being boundary lubrication, therefore, what he meant was that in some part of the bearing—possibly only a very small part—there would be boundary lubrication. Dr. Clayton's sketch assumed that throughout the whole length of the bearing there was a nice, neat, even gap between journal and bearing, with a nice, even thickness of lubricant. Production engineers, however, did not make bearings as perfect as all that. At one end the journal would almost certainly be nearer the bearing than at the other end, and particularly with normal journal finishes, there would be grinding ridges or other high spots on the journal pressing through the oil film where it was at its thinnest. He agreed that over much of their mating area journal and bearing might well be separated by a fluid film of oil, but he contended that the reason bearings overheated, why they sometimes seized, and why journals suffered from wear, was because at some points the film was broken through and more heat generated than could be accounted for by fluid friction. If this were not so, if all the friction were, in fact, caused by shearing of the oil film, then why did one bearing material differ from another as shown by the extent to which it heated up, or wore the journal, or was liable to seizure when conditions in other ways were the same.

The bearing manufacturer who had to specify a bearing material

had to remember that he was not dealing with people who made perfectly accurate and rigid bearings and journals, and that over areas of high pressure, oil films would be very thin, while at high spots there would be metal to metal contact. It was only because of the departures from what should happen that the softer materials had the enormous advantages which they possessed ; their supreme merit was that they were kind to careless production engineers.

Dr. Clayton mentioned the two-stroke gudgeon pin where the grooves were needed, so that in the cycle of movement every bit of the loaded part of the journal at some time came opposite a groove and got some oil on it before it went back on duty. It never had any other chance. The chief designer of his firm had told him that the two stroke gudgeon pin bush was one of the most heavily loaded positions for which he had to design, and it was only by the cross oil-grooves that it was possible to keep a film of oil between gudgeon pin and bush.

He endorsed what Dr. Clayton had said about the gain in the strength of white metal by making it thin. The Americans, faced during the war with almost a complete lack of supply of tin, had to switch over to lead babbitts with only 1 per cent. of tin, and they did a marvellous job with them. To-day the Chevrolet big-end was lined with lead babbitt having a thickness of only 0·004 inch nominal, and would range from about 0·0025 to about 0·005 inch. It was fitted very tightly, with less than 0·001 inch clearance, but that heavily loaded big-end was magnificently lubricated. Bearings as thin as that had, as Dr. Clayton said, remarkable fatigue strength because of the support given from the back.

He had been very interested in Dr. Clayton's theory about the air lubrication of spindles running in tight-fitting bearings. It was something which wanted thinking over, but it sounded reasonable and likely, and helped to explain the coolness of running. Personally all he could really do was to report what happened in practice and the theory was something which he and Dr. Clayton would no doubt be talking over before long. Production engineers need not bother about the theory as long as the idea was good in practice.

The oil window which he had mentioned was a recent development, not yet fully tried out. If one imagined a spindle with a hole down the middle, with a taper hole drilled from side to side and filled with a porous bronze plug and the whole surface rounded off, that would give an idea of it. The centre contained a plentiful supply of oil, and there was between journal and bearing a porous device which metered the oil and allowed it to percolate into the space between journal and bearing. As with the porous bearing, when the temperature rose the oil became less viscous and more oil came on the job. This new idea was intended largely for use in situations where loose oil was undesirable. Textile machinery was a good

example. One could provide a really large oil supply tank if desired, and the oil would be metered as required. That was perhaps of greater interest to the designer than to the production engineer.

MR. H. C. GODFREY asked why machine toolmakers so often stuck to bronze or gunmetal bearings in view of the fact that they seemed to have so many disadvantages. One or two of those disadvantages had been mentioned by the author, but the greatest of them all, in his view, was that with oil-can lubrication, sooner or later the bearing was allowed to run dry and it squeaked ; when that happened with a bronze bearing it was ruined ; the shaft became roughened and it was no use oiling the bearing then ; the shaft had to be reground. All the machine tools with bronze bearings with which he had had anything to do had suffered from that trouble, and it was their custom to bore the bronze bush out and line with white metal, and if the machine then ran short of oil, as it would sooner or later with oil-can lubrication, the bush might be damaged slightly, but not the shaft. He was talking about lightly loaded bearings in lathes and so on. There must be some reason why the makers fitted bronze bushes, but he could not understand what it was.

The author had not referred to floating bushes. Personally, he had had a good deal of experience with them. If one had a heavily loaded bearing which gave trouble, and one could possibly put in a floating bush, one would find that it was possible to take about double the load. A floating bush had another advantage, in that if one strained a shaft endways in an ordinary bearing one was liable to wear the shaft in grooves in time, but if one had a floating bush, the bush could float endways and the shaft could still be constrained. It seemed to him that floating bushes had a big advantage. The first experience that he had had with one was on a steam locomotive many years ago, which for some unaccountable reason was eating up bushes in its coupling rods in about 1,500 miles. One of the fitters suggested that a floating bush should be put in ; that was done and a very big mileage was obtained without further trouble. He believed that the London buses, before they went to ball-bearings or whatever they used now, also used floating bushes, at a time when ball or roller bearings would not stand up to the load. He had in mind the buses used at the time of the last war, which were called the "Old Bill" buses. They tried fixed bushes, but they were not satisfactory. They put bronze sleeves in with a lot of holes drilled in them, and they seemed to work quite well. He would like to have the author's comments on floating bushes.

MR. TAIT said he had often asked himself why machine tool designers used so many phosphor-bronze bushes. He thought that perhaps one of the reasons was that white metal bushes had in the distant past been rather expensive ; they had had to be rather thick

and so were perhaps a little difficult to use. That excuse was not valid to-day. In America they hardly use phosphor-bronze bushes at all, but white metal lined bushes are much more in evidence there than they are over here. Dr. Schlesinger was using white metal in a high precision lathe, and he entirely agreed about their good properties. In the bi-metal bush of steel lined with white metal one had something so convenient and cheap that it was very desirable to use it whenever possible. One of the main purposes of this paper was to urge people to think more of the use of white metal for machine tools and similar applications.

The question of the man with the oilcan often came up, but he would suggest that it was time to get away from him altogether and to design a lathe or other machine tool which lubricated itself. Nothing could be more inefficient than a man with an oilcan. One should fit a drip oil feed lubricator or take other steps to get the oil where it was wanted, not simply when one happened to think about it or when it began to squeak, but all the time. He would urge everybody to take steps in that direction, and to try white metal first. If that proved too weak, then they should try lead-bronze, and only if that failed should they turn to phosphor-bronze. Phosphor-bronze was the last thing to consider and should only be used where it was not possible to use anything else. This must not be taken as belittling phosphor-bronze. There were places, but not many, where it was essential, particularly for slow speeds and very heavy pressures, but when speeds were a little faster and loads a little lighter, you could use lead bronzes or copper-lead, while as speeds increased, first phosphor-bronze and then lead-bronze became unusable, and the white metals held the field. As an illustration, at a very low speed a particular bronze bearing might be capable of carrying a load of say, 15,000 pounds per square inch. Increase the speed to 500 circumferential feet a minute and this would have fallen to a mere 50 pounds, and at a little higher speed, rate of heat generated would be faster than heat dissipation, and load carrying capacity would ominously vanish.

At these higher speeds the white metals would be in their element, enjoying themselves and keeping cool.

He wondered whether in the floating bush cases quoted by Mr. Godfrey (with the exception of the point about scoring ; if there was scoring it would appear that something was wrong) it would not have been even better to shrink the bush on the journal and let it articulate inside a cast iron or hardened steel shell. A case came to his mind which concerned one of the most difficult bearings with which he had ever had to deal. It was a floating bush, and he believed that it was for some years lined inside and out with a cadmium-nickel alloy as the only material that would stand up to the high temperatures involved. (Floating bushes could become very

hot because heat dissipation was usually poor). One day the temperature suddenly dropped and everything ran better, and when an examination was made it was found that the bush had seized on to the journal. From that time onwards they shrank the bush on to the journal. In cases where there was difficulty in finding a material to stand up it might often be found that if the bush, instead of being allowed to float, was fixed on to the journal it would be better. He thought that the floating bush was a sort of halfway house. It was extraordinarily unlikely that the speed would be divided between the two surfaces, because the pressure areas were so different. The bush probably rotated with one and not with the other, changing over when one or the other tended to drag or seize. To have the bearing material on the journal rotating inside a hardened steel, or cast iron sleeve, was often a very satisfactory arrangement.

MR. MARLOW asked whether the theory of oil film lubrication and the clearances of the bearings which had been mentioned were applicable to bearings which were water-cooled. For instance, there were many bearings for which it was not possible to use oil, as for food machinery, pumping units and so on.

Secondly, he would like to know what was the best means of lubricating bearings of the force pressure type as used on heavy roller mills, this being a type of bearing which had always caused difficulty regarding lubrication and consequently had a very short life.

It might also be of interest to mention that he had had experience with bearings where lubrication was very unsatisfactory owing to the atmosphere where the bearings were situated being heavily laden with dust, and also the temperatures being high, and in this case the bronze type of bearing which existed was replaced with special bearings made from granite, and it was interesting to note that this type of bearing had been in operation for many years without any lubrication being added whatever.

Leaded bronze had been mentioned as a successful bearing metal, but he had found this quite useless with water lubrication.

MR. TAIT said that water-lubricated bearings had always presented a problem, and that lead-bronze bearings should break down in such circumstances was only to be expected ; the water would attach the lead and leave one with a surface which was not suitable for a bearing. Lignum-vitae was satisfactory in some cases.

With rubber rolls the pressure could be very high, and there was no relief at all. The only way of deciding how to get the oil under pressure between journal and bearing was to study the individual design and decide on the best method for that particular case. It might mean an oil groove here or an oil groove there designed tó form a wedge to get the oil in. It was always a problem, and it was not a matter where a general rule could be made.

Granite was to some extent like graphite, and there may be something in the nature of shearing or crumbling of the surface going on, but he could not pretend to any great knowledge of the subject.

MR. MAER asked whether the strength of the bond between the white metal lining and the harder backing metal was important and, if it was important, whether that helped one to choose the material to be used as the backing material, and for instance to choose steel as against some of the gunmetals or bronzes. Mr. Tait had referred to the fact that one should avoid putting oil holes into the load area of the bearing. It would be of interest if he would say why that should be avoided.

MR. TAIT emphasized that it was of the first importance to have a true bond. That was why cast iron was not a popular material for backing. It was *possible* to bond white metal to cast iron ; a method had been in use for some years in America, and a rather better method had recently been worked out in this country at the Tin Research Institute, for tinning cast iron so effectively that a satisfactory bond could be obtained ; but it was difficult, and that was why in general steel, which gave the best bond of all, was the preferred material. Gunmetal did not give as good a bond, because the tin-copper compound did not give such good adhesion as the tin-iron. Speaking generally, the best bond meant the best bearing ; steel gave the best bond, and therefore steel was to be preferred, other things being equal.

He thought that Dr. Clayton had answered the question about the oil holes by the sketch he had made on the blackboard. If one had the oil hole somewhere near the pressure area, one would spoil the building-up of pressure into what he himself called the pad, and what Dr. Clayton called the full fluid film. Instead of forcing oil in, one would be letting oil out ; the main entrance would have become an emergency exit.

MR. BUCKLEY expressed some disappointment that there had been no mention in the lecture of thrust bearings. He had had a good deal of trouble recently, he said, with that type of bearing, particularly on hydraulic pumps where they used a vane type pump and a rotor—sometimes a floating rotor—between two side faces. They could find nothing that would stand up satisfactorily except really hard steel. The oils which they used were rather thin and of a paraffin type, D.T.D. 44 and similar, and the running speed would be about 2,000 ft. per minute, with a pressure of the order of 500 to 700 lbs. per sq. inch. They tried cast iron and steel, and that was not very satisfactory ; the only two that stood up for comparatively long periods were nitrided steel against nitrided steel, and nitrided steel against cadmium plating. The difficulty with cadmium plating

was that although it worked very well they never found a method of making it stay on.

The author had said nothing about the lubrication pressure which should be used on a bearing. He believed that Dr. Ricardo some years ago carried out experiments on big-ends and obtained remarkable results, loading the bearing with an oil pressure equivalent to the thrust load of the bearing.

MR. TAIT said that he had not dealt with thrust bearings because they formed a subject in themselves, and the paper was confined to sleeve bearings. They had found that in the case of a thrust washer it could be very valuable to let it float. There was little chance for a thrust washer to form a nice fluid film such as you could get in a journal bearing. However, pressure on a thrust washer was never uniform and probably the reason why the floating thrust washer was so much better was that at the first hint of seizure it turned round, and the new piece of washer which came round into the pressure area probably had an oil film on it. They had known instances where thrust washers had had a short life, but putting in a floating washer had overcome the trouble. He would not like to offer any specific suggestion, however, without knowing much more about the particular application, but the floating washer was just something to bear in mind.

On the question of oil pressure, in general it was true to say that the higher the pressure the better. Dr. Underwood had designed a beautiful testing machine in which he wanted to measure the torsional drag due to friction. He provided an inner housing and an outer housing, ground perfectly to a clearance of about 0·002 in. and between the two he forced oil from many entrances under great pressure, thus actually floating his inner housing inside the outer with a 0·002 in. oil film. In this way, he got almost a frictionless movement. There was no actual rotation between inner and outer housings, because the tendency to turn was taken upon a flat spring. Deflection of this spring was measured and indicated the torsional force.

However, on the question of oil pressures he could not claim to be an authority, and there were others more qualified to deal with the matter than he was ; but he was sure that even the experts would ask to see the particular application before making any recommendations. It would probably be realised by now that bearing problems were such that many heads had to be put together to solve any difficult problem.

MR. HOARE, dealing with the question of lining thickness raised by Dr. Clayton, said that the author had indicated that on a Chevrolet bearing they had got down to a lining thickness of about 0·004 in. Presumably such linings were cast in the rod, and precision bored before assembly. He wondered whether one could anticipate

getting down to such a low thickness with a pre-finished white metal lined bush. Obviously questions of manufacture, assembly and service would all arise. He thought that the meeting would welcome an expression of opinion on the point.

Mr. Tait said that he had referred to these particular big ends because they were produced in enormous numbers, and they were lined and machined in the rod. Production engineers would realize that this was a remarkable feat, and he had been very interested to see how they did it. They could not produce them to the required accuracy, and so they had to work by selective assembly, to limit their clearance to between 0·0004 and 0·0009 in.

Much more important, he thought, were the pre-finished bearings with linings nominally 0·0025 to 0·0040 inches thick, which were also used. These were made out of bi-metal strip. A particular case was the Durex bearing with a lining only about 0·003 in. thick, and that was being made to pre-finished size ; that was very definitely a production engineering problem, as could be imagined. These bearings with ultra-thin linings were made in large numbers. His own firm were making these, and they did not much like the job—nobody did, because there were quite a lot of manufacturing headaches attached.

His doubt was whether now that the war was over, there was the need for them. The American development and use of these thinly lined bearings must be looked upon as a really marvellous war-time development which enabled them virtually to do without tin, because with only 1 per cent. of tin in a bearing 0·003 in. thick there was very little tin used, compared with having 80 per cent. tin in a bearing 0·020 in. thick. He did not consider, however, that to-day these bearings were as useful as other types. Their extreme thinness made them intolerant of any dirt in the oil. Their cushioning effect must be low ; there was so little of them to "give". It was possible to obtain remarkably good results with these thin bearings if the oil was kept very clean and nothing went wrong, but personally he liked to have a larger factor of safety, and he considered, therefore, that it was time to weigh up their value again. With thicknesses of 0·007 to 0·010 in., one had something rather more attractive and with the tin babbitts in particular, one had gained almost all that one could gain by reducing thickness.

Pre-finished bearings with a 0·007 in. lining were quite simple to produce, and they much increased the load-bearing capacity of the white metal lining. In the old days, linings were used, especially in ships, which were as much as ¾ in. thick, which meant going to great trouble to ensure bonding and involved great expense. In such cases, it would be much better to change to thinner linings.

Mr. Freeman, referring to the question of self-lubricating bronze bearings, asked whether it would be possible for a normal engineering

concern to buy the material for use for experimental purposes on an experimental machine to produce small quantities of non-standard bearings.

MR. TAIT said that if that question referred to the ordinary self-lubricating type of bearing, the ordinary oilite type, he would imagine that to produce very small numbers would be very expensive. It *could* be machined, but it was not easy, and would probably call for a diamond tool, very keen and of the right shape. For the ordinary production type of bush, one would not dream of machining them, because it was unnecessary, and was also liable to close up the pores and spoil the self-oiling properties ; but if it was desired to have a small number to fit on an existing test machine, he imagined that the manufacturers would be capable of making them.

He would like to say a word about bearing testing machines. Everybody he met who came into the bearing business announced that he could design a universal bearing testing machine, and they all ended up with a broken heart after trying it. There was no bearing testing machine apart from the actual job, which would reproduce *everything*. There were so many factors involved that if one wanted to design a bearing testing machine for an engine bearing, the best thing to have was the engine.

On the other hand, it was often desired to make comparisons of materials, and for this purpose it was often possible to make a simple set-up which took the two materials, one of which was known and the other not, and treat them as far as possible in exactly the same way. Comparison could be made by measuring the temperature rise and frictional drag, but not the coefficient of friction, because there is no certainty as to exactly what that means in a lubricated bearing. If the new material did not heat up as much as the other or the drag were less, it was probably better.

If one wanted to make a bearing test one had two options. One was to make up something which resembled as closely as possible the part of the machine which it was desired to test, if the test could not be conducted on the machine itself. The other was to have some device in which it was possible to compare the present material on which it was desired to improve, and the other which it was desired to try under identical conditions of lubrication, heat absorption, and so on, and compare the temperature rise, etc. Such a device was often very simple to make and could be very informative.

MR. URWIN said that the author had mentioned various materials graded by softness. Some years ago for a particular purpose hard steel was successfully used in a bearing in a machine tool. It might be that the latest developments had shown that the softest material gave the greatest accuracy, as the fine boring machine had proved, but he wondered whether those hardened steel bearings were still used.

Secondly, they had been recommended to use standardized bearing bushes. Would that refer to standards drawn up by the author's company or by any other, or was there a British standard? There was a British standard for oilite type bushes, but was there also a British standard to which any designer could refer for any sort of bearing bush with regard to size?

An optimum length ratio of 0·7 had been mentioned. If one wanted to go under that, where did the difficulties come in? He understood that one of the difficulties in a short bearing was to retain the film of oil, but it had been proposed a few years before the war to use a sleeve bearing, which would be interchangeable with a ball bearing, which meant that the length of the bearing would be considerably shorter than was customary in sleeve bearings, coming down to about 0·3 of the diameter. Such bearings had been successfully employed. He thought that they were very little known in this country, but they had been used on the Continent, and he wondered whether anything further was known about them.

Mr. Tait, dealing with the question of hard steel against hard steel, said that without knowing very much more about the particular application it was difficult to say much, but one could quite imagine that if the lubrication was satisfactory and there was always oil under pressure, so that the two steel surfaces never came together, it might work well, but it did call for extreme rigidity and accuracy of production, and he thought that from the production point of view one would not use it, unless nothing else could be employed. It was well known that tungsten carbide centres were used in lathes, but speaking generally the difficulties increased with the harder materials, and he suggested the use of the softer materials because they reduced the difficulties.

On the question of standards, he hoped that there would in time be British Standard Specifications for bushes. It must be remembered, however, that to carry large stocks of standard sizes, covering a sufficient range of sizes perhaps going from ¼ in. bore up to 4 in. bore in all lengths for each diameter and with different materials—white metal, copper-lead, lead-bronze and so on—called for a big layout on tools as well as the laying down of very large stocks of standard bearings so that it would probably be found that only the larger companies would be able to carry those stocks to begin with. That was really the only difficulty.

His own company had taken the plunge and drawn up their own standards, arranged as intelligently as possible and covering a very wide range. It had required a tremendous amount of tooling with a different tool for every size. He hoped that these standard sizes would be accepted by users so that they would always specify them, then all tools made would fit in with an ordered plan, and in

time all manufacturers would build up their range of standard tooling. They must remember that metric sizes were also needed.

Unlike cast and machined bushes, pressed bushes must be made in thousands, but users often needed fifties and hundreds. This could only be managed with standards sizes and manufacturers' stocks. Of course, if any user wanted many thousands of a non-standard size there would be no difficulty in making the special tooling required. But even so, with so many sizes covered by standards only a very special reason could justify departing from standards.

With regard to the length ratio, where a figure of less than about 0·6 was employed, because the very edges of the bearing were not very effective, poorer results were obtained. For reasons of a practical nature, the optimum ratio was about 0·7 and doubling the length did not necessarily double the load-carrying capacity, but halving it to below 0·6, much more than halved the capacity. Putting it briefly, production engineers could be well advised to design for a length/diameter ratio between 0·7 and 1.

Mr. Mason, who proposed a vote of thanks to the author, said that when he left the meeting he would do so a far wiser man than when he entered it, and the assimilation of the knowledge which he had gained had been made very pleasant. He would like to thank the author for clearing up a mystery which had puzzled him ever since the early days of his apprenticeship, the daily experience in the starting up of a plain grinding machine. Every morning there was great difficulty in starting up the machine, but one day a new man arrived whose simple expedient, which enabled the machine to be started with the greatest ease, was to remove the lubricators. From that day forward everyone else copied it, and that ended the trouble, but until that evening the reason for the success of the method had not been clear to him. A great debt of gratitude was due to the author for an excellent lecture.

The vote of thanks was carried with acclamation, and the meeting then terminated.


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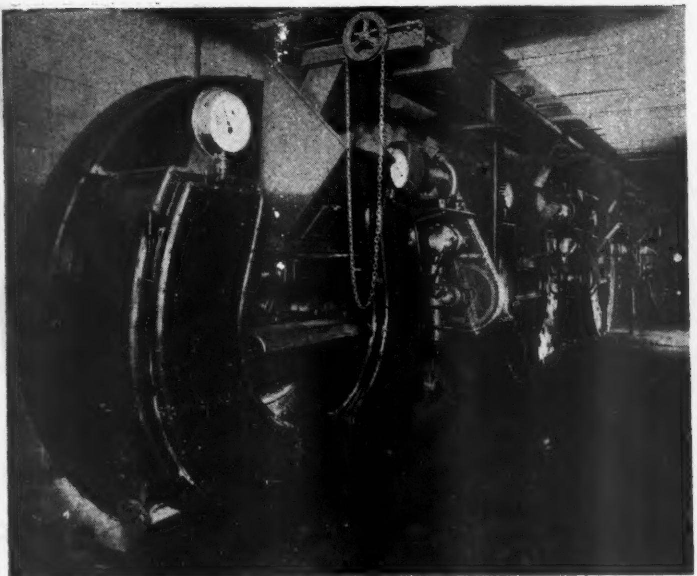

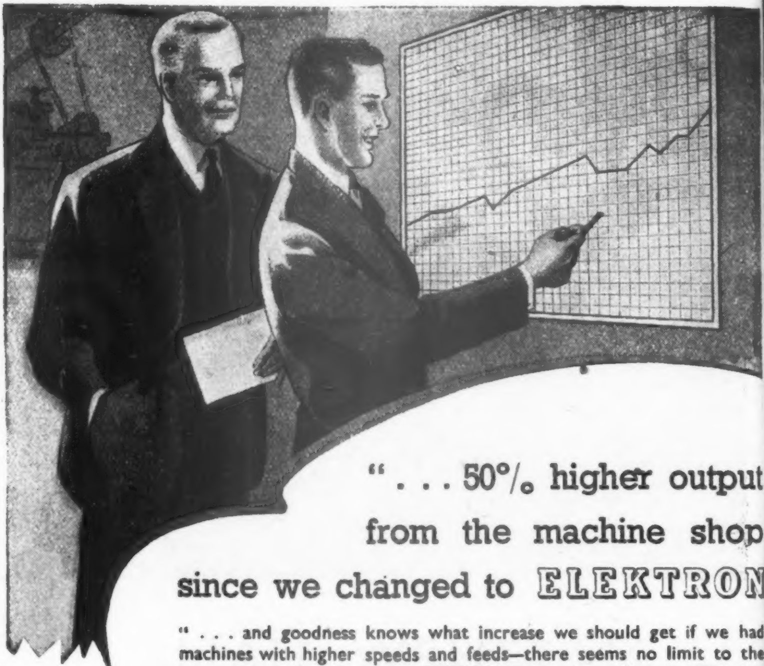

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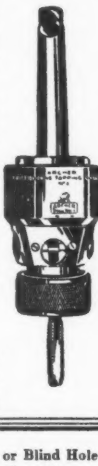

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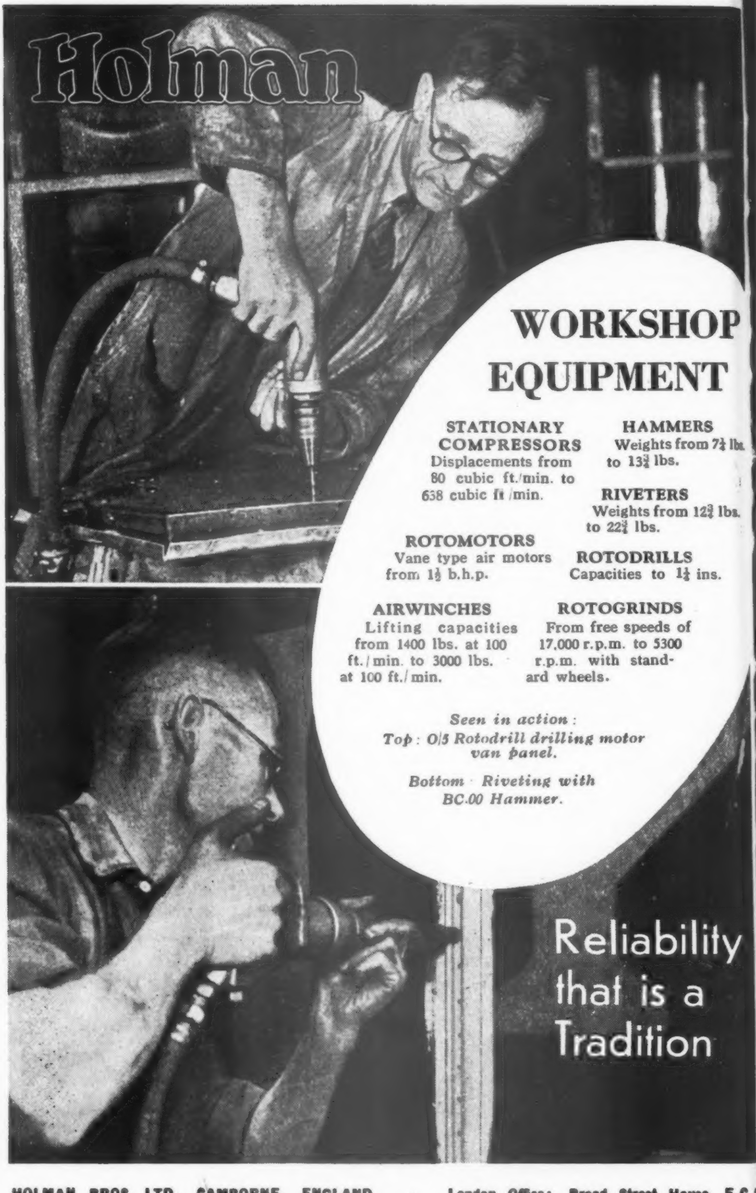

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